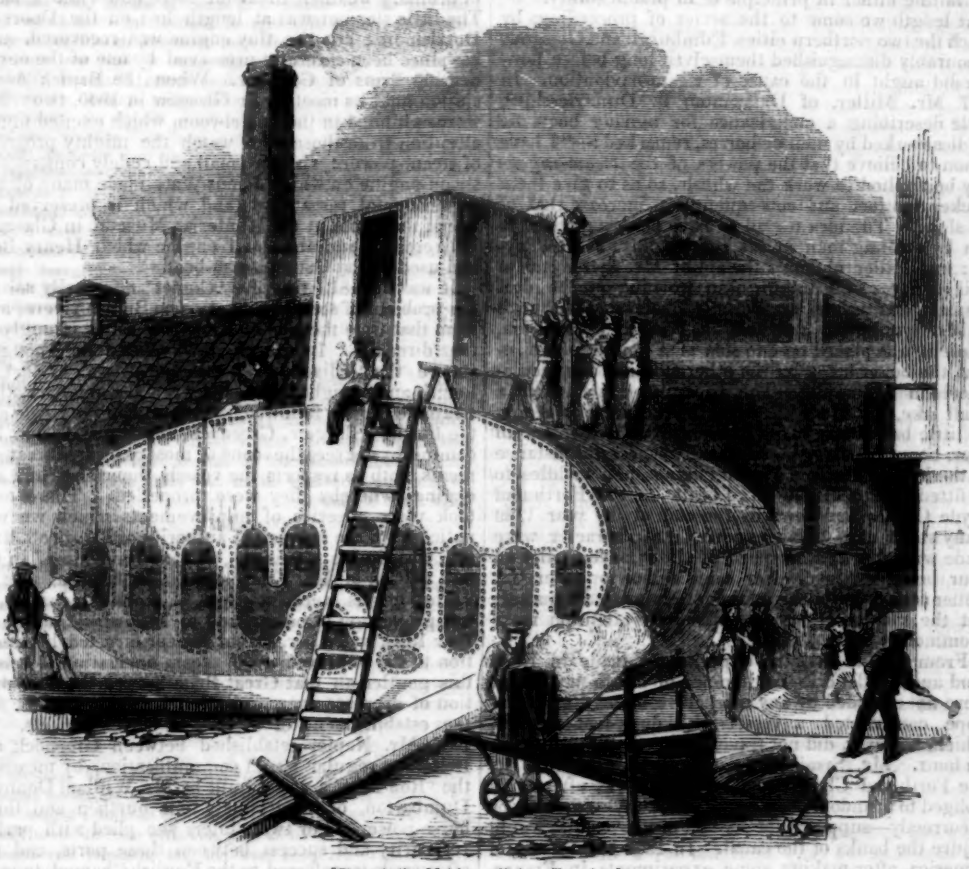
A DAY AT THE CLYDE STEAM-BOAT WORKS.



[Steam-boiler Making.—Vulcan Foundry.]

It has been said of the River Clyde—the Thames of Scotland, as regards commerce—"Compared with the bulk of its waters and the breadth of its stream, it is probably unsurpassed in the world for the quantity and stir of its navigation; not only bearing along ships of heavy burthen and deep draught of water, and plentifully dotted with yawls and wherries, but kept in constant foaming agitation by large steam-ships bearing heavy cargoes from the shores of England and Ireland, by numerous coasting steam-vessels careering over its surface with live freights of human beings, and by steam tugboats dragging behind them trains of sailing-craft too unwieldy to pilot their own way within its narrow channel."

The Clyde is so connected with the commercial enterprise of the country, with the rise and progress of steam-navigation, and with the construction of steam-boats and marine steam-engines, that we have thought a notice of the Steam-Engine Factories of Glasgow might enable us at the same time to glance at a few matters which well illustrate the relation of these factories to the commerce of that busy city. The name of Napier is deservedly noted in connection with marine steam-engines at Glasgow; but the same name also occupies a place in the history of the progress of steam-navigation; and the one may be made to illustrate the other.

How the labours of many men led to the gradual development of the idea that steam might be brought to act as a moving-power for ships, has been largely treated in various publications and forms, indeed the subject of many bulky volumes. When the Marquis of Worcester, in his 'Century of Inventions,' spoke of an invention by which he could "make a vessel of as great burthen as the river could bear to go against the stream, which, the more rapid it is, the faster it shall advance, and the moveable part that works it may be, by one man, still guided to take the best advantage of the stream, and yet to steer the boat to any point"—it is supposed that he alluded to some kind of steam-engine; but we are left wholly in the dark as to whether the matter was anything more than a speculative conjecture in his own mind. Savary and Papin tried to bring steam to bear upon navigation; and in 1737 Jonathan Hulls published a pamphlet in which he explains a clumsy but ingenious mode of constructing a steam-boat; but there is no evidence that he reduced it to practice. Then followed Daniel Bernoulli's essay on the practicability of propelling vessels by paddle-wheels urged by steam; then a similar essay by Gau-

tier; then a proposal, by a Genevese minister, to use propellers acting on the principle of the duck's foot; then various plans proposed by D'Auxiron, Perier, and Jouffroy, in France, and by Rumsey, Fitch, and Evans, in America—all exhibiting more or less ingenuity, but failing either in principle or in practicability.

At length we come to the series of proceedings by which the two northern cities, Edinburgh and Glasgow, honourably distinguished themselves, long before London did aught in the cause of steam-navigation. In 1787 Mr. Miller, of Dalswinton in Dumfriesshire, while describing a contrivance for moving boats by paddles worked by men or horses, remarked:—"I have reason to believe that the powers of the *steam-engine* may be applied to work the wheels, so as to give them quicker motion, and consequently to increase that of the ship." The idea is said to have been suggested to him by a young man in his service, Mr. James Taylor; and Miller obtained the aid of Mr. Symington, a civil engineer of Edinburgh, in working out the idea. A small engine was accordingly made at Edinburgh by Mr. Symington, and sent in 1788 to Dalswinton, where it was placed on one side of a double pleasure-boat, the boiler being on the other side, and the paddle-wheels in the middle. The apparatus was tried in a small lake, and Mr. Miller had the pleasure of seeing his little bark move along at the rate of five miles an hour, being perhaps the first really successful instance of the kind. He then caused engines and paddles to be fitted to one of the large boats on the Forth and Clyde Canal; and towards the end of the year 1789 many short trips of an experimental character were made with this boat, a speed of six or seven miles an hour being attained. For some reason or other Mr. Miller ceased to pay any further attention to the matter; but the success of his attempts drew attention more prominently to the subject.

From 1789 to 1812 the experiments made in England and Scotland in furtherance of steam-navigation were not attended by any marked results. Earl Stanhope constructed a vessel with duck-foot paddles, which, however, did not travel faster than three miles an hour. Mr. Symington made a steam-tugboat for the Forth and Clyde Canal, which he was afterwards obliged to abandon, because the Company—correctly or incorrectly—supposed the motion of the paddles would injure the banks of the canal. In 1806 Mr. Fulton, of America, after making some experiments in France, procured all the practical information which Symington, Miller, and others could give him in Scotland, and succeeded after a time in running a steam-boat on the river Hudson, in America, from New York to Albany, being the first instance of a steam-boat commercially used as a passage-boat, the preceding attempts in Scotland having been rather experimental than commercially practical.

It appears that Mr. Henry Bell, whose name is associated with the rise of steam-navigation on the Clyde, had been instrumental in procuring for Fulton various items of information from Mr. Miller; and in a short paper which he contributed to the 'Caledonian Mercury,' in 1816, after alluding to a letter which he had written on the matter, he uses this remarkable expression:—"This letter led me to think of the absurdity of writing my opinion to other countries, and not putting it in practice myself in my own country; and from these considerations I was roused to set on foot a steam-boat." He made many attempts with partial success, and at length produced the little steam-boat 'Comet,' which will always be remembered in connection with this subject, as the first steam-boat made in Europe which successfully plied as a passage-boat. It was built by Messrs. Wood, of Port-Glasgow, on the Clyde. It was only forty feet in length of keel, with about ten feet beam; its tonnage was about twenty-five tons, and it was worked by a little engine of three horse-power. The 'Comet' plied on the Frith of Forth, between Grangemouth and Leith, a distance of twenty-seven miles, which it was accustomed to do, in ordinary weather, in about three hours and a half. The little steamer was at length lost on the Doors of Dorrismore; but the tiny engine was recovered, and has since been carefully preserved by one of the engineering firms of Glasgow. When the British Association held its meeting in Glasgow in 1840, two relics were exhibited in the model-room which excited much attention from those who watch the mighty progress of steam-power: viz. the small and rudely constructed steam-engine on which James Watt made many of his experimental researches (and which is preserved in one of the rooms at the Hunterian Museum in Glasgow University); and the small engine which Henry Bell had used in the Comet steam-boat.

It was in 1813 that the 'Comet' effectually solved the problem of steam-navigation on British rivers; and from that time the tide of enterprise set in strongly in that direction. In March, 1815, Mr. John Thomson started the 'Elizabeth,' a steamer fifty-eight feet in length and of eight horse-power; and numerous other steamers rapidly followed, principally on the Clyde and the Forth; Glasgow, Greenock, and Port-Glasgow becoming by degrees the scene of most extensive arrangements both as respects the vessels themselves and the engines whereby they were propelled. There next took place a series of improvements which we will notice from the competent authority of Mr. Scott Russell, who, in his treatise on 'Steam-Navigation,' in the new edition of the 'Encyclopædia Britannica,' says:—"The vessels were, however, of small dimensions, of low proportion of power, and of little speed, until the year 1818, when Mr. David Napier directed his attention to the improvement of steam-navigation. It is to this gentleman that Great Britain owes the introduction of deep-sea communication by steam-vessels, and the establishment of Post-office steam-packets. In 1818 Mr. Napier established between Greenock and Belfast a regular steam communication, by means of the 'Rob Roy,' a vessel built by Mr. William Denny of Dumbarton, of about ninety tons burthen and thirty horse-power. For two winters she plied with perfect regularity and success between these ports, and was afterwards transferred to the English Channel, to serve as a packet-boat between Dover and Calais. Having thus ventured into the open sea, Mr. Napier was not slow in extending his range. Soon after Messrs. Wood built for him the 'Talbot,' of one hundred and twenty tons. With two of Mr. Napier's engines, each of thirty horse-power, this vessel was in all respects the most perfect of her day, and was formed on a model which was long in being surpassed. She was the first vessel that plied between Holyhead and Dublin. About the same time he established the line of steam-ships between the stations of Liverpool, Greenock, and Glasgow. For the traffic of these stations he built the 'Robert Bruce,' of one hundred and fifty tons, with two engines of thirty horse-power each; the 'Superb,' of two hundred and forty tons, with two engines of thirty-five horse-power each; and the 'Eclipse,' of two hundred and forty tons, with two engines of thirty horse-power each. All these were established as regular deep-sea traders before the year 1822."

It will be observed that nearly all the steam-boats and steam-engines here mentioned as being constructed on the Clyde, were worked not on that river, but in the open sea; and if we trace the past progress of the city of Glasgow we shall perceive a reason for this. There does not exist, perhaps, a parallel instance throughout Europe to the improvements which Glas-

gow capital and enterprise have wrought on the river Clyde. In other places sand-banks, bars, and obstructions to the free navigation of a river have been removed, quays have been constructed, and river-walls built; but for a large maritime commerce to be actually *created* by such means, is what we rarely find to be the case. At the beginning of the present century, only small craft of thirty or forty tons could get up the Clyde to Glasgow; and persons now living well remember when weeks elapsed without a keel reaching up to the city; whereas now vessels of six or seven hundred tons, and drawing sixteen feet of water, can come up to the very bridge of Glasgow; and indeed vessels of as great burthen as seventeen hundred tons have been fitted with their engines close to the quay at Glasgow; while at some tides a depth of twenty feet water is procured close to the bridge. This mighty progress is closely connected with the spread of steam-boat operations in Scotland, and may fittingly be noticed here in a brief manner.

Until the recent improvements in the Clyde, the harbour for Glasgow, in respect to foreign commerce or coasting trade, was many miles from the city. About the middle of the sixteenth century, the Clyde being so much impeded by fords, shoals, and banks as to be scarcely navigable for any craft above the burthen of an open boat, the inhabitants of Glasgow, Renfrew, and Dumbarton agreed to labour on the river six weeks alternately, with the view of opening up a communication between these places for small craft. A government commissioner having to report on the revenue of Scotland in 1651, and having spoken of the trading operations of the Glasgow people, said:—"The mercantile genius of the people is strong, if they were not checked and kept under by the shallowness of their river, every day more and more increasing and filling up, so that no vessel of any burthen can come up nearer the town than fourteen miles, where they must unlade and send up their timber on rafts, and all other commodities by three or four tons of goods at a time, in small cobbles or boats of three, four, or five, and none above six tons a boat." The Glasgow merchants first had their shipping-port in Ayrshire; but wishing for a spot more convenient, they tried Dumbarton, and afterwards Troon, but were repulsed at both, for the sapient reason (in the first case), "that the influx of seamen would raise the price of provisions to the inhabitants;" and (in the second), "that it would occasion a rise in the price of butter and eggs." They succeeded ultimately in purchasing a piece of ground on the south bank of the Clyde, where in 1662 they constructed the first dry-dock in Scotland, at the spot which thenceforward obtained the fitting name of 'Port-Glasgow.'

Until the Union with England, nothing occurred to extend the commerce or shipping of Glasgow very rapidly; but that event gave an extraordinary impetus to the city, by opening a trade with the colonies. The Glasgow merchants at first chartered vessels from Whitehaven and other ports, and filled these vessels with British goods, which were bartered for tobacco in the American colonies. By degrees, however, they made their operations centre more decidedly in their own city; and in 1718 the first vessel owned by Glasgow merchants crossed the Atlantic. The traffic was carried on so spiritedly that the tobacco importers of the English ports loudly complained, and succeeded in obtaining enactments which severely crippled the Glasgow merchants. They survived the shock, however; and by 1772, out of ninety thousand hogsheads of tobacco imported into Britain, Glasgow alone imported more than half; one merchant possessing twenty-five ships engaged in the trade. The great tobacco-merchants formed at that time the aristocracy of Glasgow; and the names of many of the streets—such as 'India,' 'Tobago,' 'Jamaica,' 'St. Vincent,' and 'Virginia'—remain to indicate the sources whence the wealth of the city was mainly obtained. Various events, among which was the American war, tended to deprive Glasgow of a considerable portion of her tobacco-trade; but the wealth which that trade had created, the ships which it had caused to be built, the habits of enterprise which it had engendered, the repute and importance into which it had brought the merchants, and the extent of intercourse to which it had given rise with other countries—all enabled the Glasgow men to strike out new fields of enterprise, which have ever since been followed with untiring energy.

Meanwhile the improvement of the Clyde (the point to which these details tend) had been going on gradually. Greenock, situated about twenty-two miles lower down the Clyde than Glasgow, became the chief ship-building port for the river; while Port-Glasgow was the recognised spot for the Glasgow merchants to load and unload their cargoes. But it is plain that they must have had a strong inducement to bring their goods up to Glasgow, instead of towing them up piecemeal, as it were, in barges. We may picture to ourselves what would occur if all the Thames shipping had to stop at Erith or Purfleet, and thence to send their goods to London by small craft; and we may thence infer what, on a smaller scale, must have been the position of the Glasgow merchants. In 1688 a small quay was constructed at the Broomielaw (the name given to the Clyde and its banks at the western part of Glasgow), and slight improvements were made in the bed of the river, so far as the funds of the corporation would admit; but it was not until the time of Smeaton that any extensive improvements were attempted. After a survey of the river by that engineer, it was recommended to render it navigable by locks; but this plan was given up for another, by which the navigation was to be improved by jetties or dykes. An act being obtained in 1770, empowering the corporation to act as trustees and to levy tolls to defray the expenses, operations commenced. In five years the engineer erected one hundred and seventeen jetties, by which the stream was so narrowed and deepened as to admit vessels to the Broomielaw drawing six feet of water. By 1792 an addition of three hundred and sixty feet was made to the length of quay or harbour at the Broomielaw, and by 1811 a further increase of nine hundred feet. But however continuous were these improvements, the spread of commerce more than kept pace with them; and the corporation were compelled to apply for increased powers in 1825, by which vast changes have since been wrought. Still greater did the commercial operations become, until at length, in 1840, another act was obtained, under which, for the next twelve or fifteen years, most extensive enlargements and improvements will take place in the river, at an estimated cost of not much less than a million sterling.

A short steam-boat trip down the Clyde from Glasgow to Greenock affords the means of observing the nature of the improvements which have been wrought. Starting from the lowest of the four bridges, we find the Broomielaw studded with ships and boats as closely as it is possible to be without injury. Steamers of a splendid character for Liverpool, Dublin, and Belfast—others of a smaller class for Dumbarton, Greenock, Helensburgh, Rothsay, and other places near the mouth of the Clyde—and trading vessels from every part of the globe, crowd this busy spot. On the southern bank there has been built a compact river-wall twelve hundred feet in length, with deep water at all phases of the tide; and on the northern bank a similar wall or quay, more than three thousand feet in length.

This at present forms the limit of the harbour; and when we get below this Broomielaw, a stranger is apt to be astonished that so much has been done with such a river. From thence onward towards Renfrew the river is so narrow that it is difficult to conceive the existence of a busy and closely-filled harbour above it: but though narrow, it is deep and regular; every yard of it for many miles is carefully watched, the bed dredged, the banks brought to a regular slope and faced with stones, useless inlets and creeks filled up, projecting points pared away, and all obstructions sedulously guarded against. Lower down the river, where the stream is of greater width, bell-shaped structures are placed at intervals on or near the banks to mark the progress of the tide; and at one point on the northern bank we see a monument which has been erected to Henry Bell, the father of Clyde steam-navigation, and one of that too numerous class of persons who fail to reap, during their lifetime, personal advantage from their ingenuity.

One effect of the Clyde improvements has been to transfer to Glasgow much of the commerce which used to be conducted at Greenock and Port-Glasgow, and with it much of the ship-building operations; while the steam-engine works have all along found at Glasgow a fitting locale. But still those two ports retain much of their past importance, and must share with their greater neighbour the distinction which "Clyde steamers" and "Clyde engines" have acquired. In some cases vessels are built at Greenock, and proceed up to Glasgow to be fitted with their engines: in other cases both vessels and engines are made by Glasgow firms; and there is seldom a day on which some vessel or other may not be seen drawn up close to the northern quay, at the western end of the Broomielaw, receiving on board either boilers or engine, or some other piece of mechanism, from one or other of the large engine-works situated in the western part of Glasgow.

We are not writing a history of steam-navigation or a description of Glasgow; but we have thought it well to give an outline of a few circumstances which show the connection between these subjects and the rise and progress of steam-boat and engine operations at Glasgow; and having done so, we will now glance within-side some of these busy establishments, and witness the general character of the processes carried on therein. Mr. David Napier, whose contributions to the improvement of steam-navigation we before alluded to, is no longer a Glasgow engineer; but the three establishments of Mr. Robert Napier, which we have been obligingly permitted to visit, will afford us the means of gathering a few notions on the subject.

Iron steam-boats have been one of the most marked objects of improvement in steam-navigation; and the builders in the Clyde and in the Thames have not been slow to follow the example set to them in this matter by (we believe) the Liverpool builders. The firm whose establishments we are about to visit rents a spot of ground on the southern bank of the Clyde, a mile or two below Glasgow, where the building of iron steam-boats is carried on; and we may shortly describe the chief points of difference between those operations and the building of a common wooden vessel.

In the Supplements for May and June, 1841, a slight account was given of the mode of proceeding in the construction of wooden ships, in connection with an extensive Thames ship-building yard; and in that account it was explained that the keel, the ribs or timbers, the stem and stern-posts, and the planking, constituted the main pieces which give shape and stability to the hull of a ship. Now in an iron steam-boat all these parts are made of iron; and the appearance of an iron steam-boat yard consequently differs much from such a one as was formerly described. There are no huge trunks of oak lying in heaps in the yard; no 'converting' sheds, where the business of sawing and shaping the timbers is carried on; no 'steaming-tank' for steaming the planks preparatory to bending round the contour of the ship; no trenail-cutters; no oakum-spinners. But instead of these there are workers in iron, with their forges, their powerful punching-engines, their enormous cutting-machines, which will sever a bar of iron as if it were a piece of ribbon, their anvils, their hammers, their rivet-furnaces; while around are lying sheets of iron from the rolling-mill, and bars from the drawing-mill, with guide-pieces for bending them to the required form. We have iron bars instead of timbers, sheet iron instead of planks, rivets instead of trenails, forges instead of saw-pits, and iron scraps instead of chips of wood.

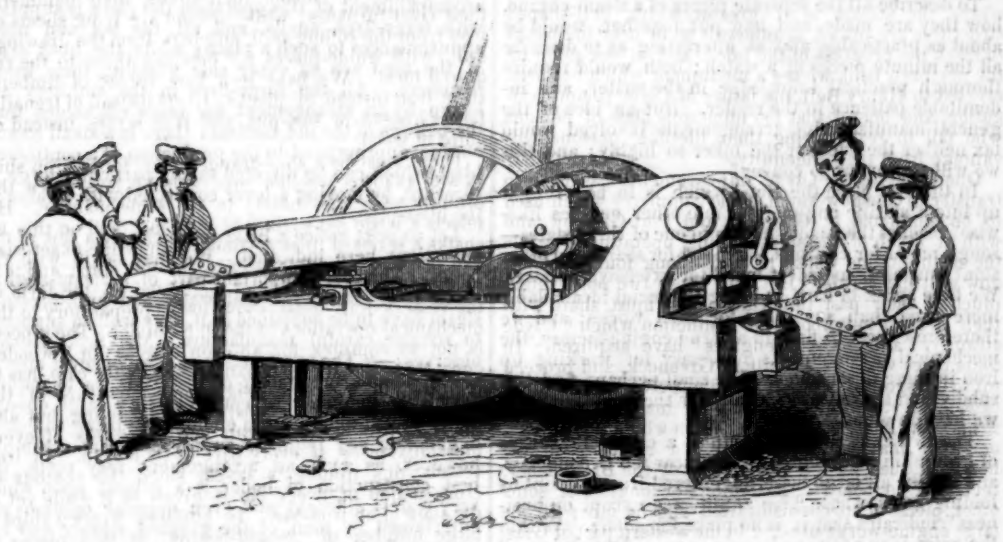
There must be a ship-draughtsman for an iron ship as well as for a wooden one, and he lays down the draught of a ship nearly in the same manner. He selects a large flat surface of flooring, and on this he chalks a series of lines destined to show the exact size and shape of the various 'ribs' of the ship; and it is here that any improvement suggested in the form of the vessel's hull must show itself, preparatory to the mechanical operations of the ship-builder. The process is not so complex for an iron ship as for a wooden one; since the draughtsman, in the latter case, has to indicate not only the height and curvature of the various timbers which constitute the framing, but also the 'scantling' or breadth and thickness of every individual piece at every part of its length. In iron vessels this trouble is saved, since the contour or cross-section of every rib is given to it while yet in the state of an iron-bar. In building wooden ships a large number of 'mould-boards' or thin pieces of wood are prepared, in exact conformity with the chalk lines on the mould-floor, as guides to the sawyers in cutting the timbers: but for iron ships thin rods only are necessary, sufficiently firm to give the curvature to the several ribs.

The keel is laid down in a slightly declining position from stem to stern, as in wooden vessels, for the facility of launching; and, like it, is generally formed of several pieces fastened end to end. But these pieces are of iron instead of wood, and are of much smaller 'scantling.' An iron keel six inches deep by three wide will suffice for a vessel of one thousand tons burthen! The various pieces of which it is formed are bevelled off at each end, so that each one may furnish a recess for receiving the other; and the two are fastened by iron bolts or rivets driven into holes bored for the purpose. The keel, standing up on one edge, exhibits a range of holes from end to end; and these are intended for the reception of the rivets which are to bind the keel, the ribs, and the 'skin' of the vessel together. The pieces of iron which form the stem and stern-posts are bent to the required form before being brought to the yard, and are then riveted to the ends of the keel: for it may be observed generally that rivets form the almost universal mode of fastening in an iron boat.

Perhaps nothing in the appearance of the skeleton of an iron vessel strikes a stranger as being more remarkable than the extreme slightness of the ribs, compared with the bulky timbers of a wooden vessel. Their cross-section is neither quadrangular nor circular, but may be described as exhibiting a square from which a quadrant has been removed at one corner. A bar measuring three inches on each of the two sides, by three-quarters of an inch in thickness, will constitute the rib for an iron vessel of considerable dimensions.

The form thus given seems to be intended to afford facilities for boring holes for the reception of the numerous rivets by which the ribs are fastened to the other parts of the vessel. The iron is brought to the exact form in the rolling-mill, where it passes between two rollers so grooved as to give the cross-section required. When it is about to be wrought into the form for the ribs of a ship, it is cut to the proper lengths, heated in fires or furnaces close to the place of working, and bent round to the required curvature on anvils; the curved rods before alluded to serving as guides to the attainment of the proper curvature. These pieces, when formed to the desired shape, are carried to the building-slip, and there riveted to the keel, at distances of from twelve to eighteen inches apart.

The sheet-iron which forms the planking or 'skin' of the vessel is a much more manageable material than the stout oaken planks employed in building wooden ships. It is rolled into sheets at the mill, of such thickness as may be desired, and cut to the requisite length and width by the powerful shears which are used in most iron and engineering works. The sheets



[Cutting and Punching Engine.]

are then brought by hammering to the proper curvature for bending round the exterior of the vessel, a guide or gauge being employed to regulate and determine the degree of curvature. They are then fastened to the ribs and to the keel by means of rivets, the number of these fastenings being extremely large.

When the keel, the stem and stern-posts, the ribs, and the sheet-covering are all put together, the distinguishing characteristics of an iron ship are nearly at an end; for the interior and upper fittings bear a pretty close analogy whether the vessel be of iron or of wood. Bar-iron for the ribs, sheet-iron for the covering, and bar and cast-iron pieces for the beams and a few other parts, constitute the metallic skeleton which is afterwards to be decked out with the finishing appendages. We saw three iron-built vessels in three different stages of progress towards completion, which afforded the means of noticing the successive steps. One was on the building-slip, the keel laid down, the stem and stern-posts erected at the ends, and about one-half of the ribs set up, constituting a skeleton whose lightness contrasted strikingly with the heaviness necessarily involved in the frame-skeleton of a wood-built vessel. Another was a very small sailing-vessel, whose progress illustrated the extraordinary rapidity with which iron vessels can now be constructed; the keel had been laid down about a fortnight before the period of our visit, and the vessel was expected to be in sailing order in another week; workmen being engaged on it as thickly as they could ply together. The third was a fine steamer called the 'Vanguard,' intended for the Irish station. This had left the building-yard, and was drawn up to the side of the quay at the Broomielaw, nearly opposite the engine-factories to which we shall presently allude, and where it had been supplied with the engines and machinery. It was a vessel of seven hundred tons burthen, and three hundred horse-power; it was about two hundred feet long, by twenty-seven 'beam' or width, and had paddle-wheels twenty-six feet in diameter. Most of the rougher portions of the work were completed; and painters, gilders, cabinet-makers, &c. were fitting up the interior in the splendid manner which distinguishes the steamers plying between Glasgow and the English and Irish ports. This, like the other two, had keel, ribs, beams, exterior coating, &c. of iron, and was an elegant specimen of this most remarkable constructive art.

We now leave the iron-boat yard, and pay a visit to the two engine-factories belonging to the same firm, both of which are in Glasgow, within a few yards of the Broomielaw quay. One of these is known as the 'Vulcan' foundry, and the other as the 'Lancefield' foundry or works; and at one or other are carried on almost the entire range of operations incident to the construction of marine engines, their boilers, and their subsidiary appendages. The writer of the article "Glasgow" in the 'New Topographical Gazetteer of Scotland,' while alluding to the operations at the Vulcan foundry, stated that the proprietor of these works "supplied the engines of the 'British Queen;' and in the course of one year, ending in October, 1840, he supplied six first-rate steam-ships with their engines, viz., two frigates, and four Transatlantic liners. The first two were the 'Vesuvius' and 'Stromboli,' which took up a worthy position at the siege and capture of St. Jean d'Acre, on 4th November, 1840; and the latter four were the Britannia, Acadia, Caledonia, and Co-

lumbia, now employed in carrying the mails between Liverpool and Halifax and Boston, North America. These liners were all built in the Clyde, are each of one thousand two hundred tons burthen, and propelled by engines of four hundred and forty horse-power." Since then, the East India steamers Berenice, Zenobia, and Victoria have also been provided with their engines from the same works. In short, the firms which are now engaged at Glasgow in marine-engineering works, including the names of Napier, of Craig, and of Todd and Macgregor, have most amply taken their share in the recent advancement of steam-navigation.

To describe all the separate pieces of a steam-engine, how they are made, and how put together, would be about as practicable and as interesting as to describe all the minute pieces of a watch; both would require thorough practical knowledge in the writer, and indomitable patience in the reader. But an idea of the general manufacturing arrangements involved would tax neither the one nor the other so highly; and this we will endeavour to convey.

In the first place the metal which is to be wrought up into a marine engine (and into other engines likewise) reaches the factory mostly in one of three states—rough metal for castings, bar metal for shafts and other stout purposes, and sheet metal for extensive surfaces. We here speak of iron, as being the metal incalculably more used than any other for such works; and we therefore expect to find, in a large engine-factory, the mechanical arrangements necessary for working up iron in these three states. We shall perhaps find this subdivision as well fitted as any for the popular sketch we have in view.

The 'Vulcan' foundry occupies a considerable area of ground in Washington Street, near the Broomielaw, and is, like all large factories, entered from without by folding-gates, whose "No admittance except on business" indicates that it is no place for idlers. Within the gates is an open quadrangle or space bounded on all sides by the buildings wherein the manufacturing operations are carried on. At the time of our visit there stood in this open area the cylinders and greater portion of the apparatus of an enormous steam-engine, about forty feet high, intended for the hot-air blast-furnace of an iron-work. On another side was a crane with an arm or lever whose radius swept round a good portion of the area, for the purpose of raising heavy weights from different quarters. On entering the buildings, the effect is very different, according to the kind of operations going on. On one side is the founding or casting house, with the sandy pit where the castings are made, the furnaces in which the metal is melted, and the other apparatus pertaining to a foundry; here, when the process of casting is not going on, the scene is the most quiet and the least bustling in the whole establishment. When we advance to that part of the premises where the boilers and funnels are made, quiet and silence are no more to be thought of. Of all the stunning and confusing noises incident to our manufactures, there is surely nothing to go beyond that which results from the ten thousand hard thumps which a steam-engine boiler receives while under the process of riveting: even when done in the open air it almost bewilders a by-stander; but when done under cover, as in the boiler-factory at Woolwich Dockyard, it is far worse. The appearance which this part of the yard presents, the enormous size of some of the boilers, the oft-repeated lines of rivets, the varied attitudes of the men while riveting, the locomotive forge at which the rivets are heated, &c., are slightly depicted in our frontispiece.

On passing within the engineering shops, the operations appear to partake more of the character of fine workmanship. The various shops are crowded with highly finished machines for working up wrought-iron into the variously shaped pieces required for steam-engine work. In the lowermost of these shops cylinders are bored, pistons fitted and adjusted, and all the heavy portions of the work prepared. There is a lathe here for turning wheels eighteen feet in diameter. Above-stairs the workshops contain benches, tools, and lathes, for preparing and finishing the smaller and finer pieces for steam-engines; as well as pattern store-rooms, pattern-making shops, &c.

In the smithery the operations are of a coarser kind. Here the forging is carried on; and as a necessary accompaniment of this operation the place is supplied with forge-fires, anvils, and all the hot and noisy appurtenances to such a place; while the lusty arms of the men are on every side wielding their heavy hammers. All the forge-fires in the smithery are blown by an arrangement far more efficacious than the bellows of the old method: there is a small steam-engine appropriated to the production of a continuous blast, which can be directed to any particular forge at pleasure, by moving a lever connected with a valve in the blast-pipe.

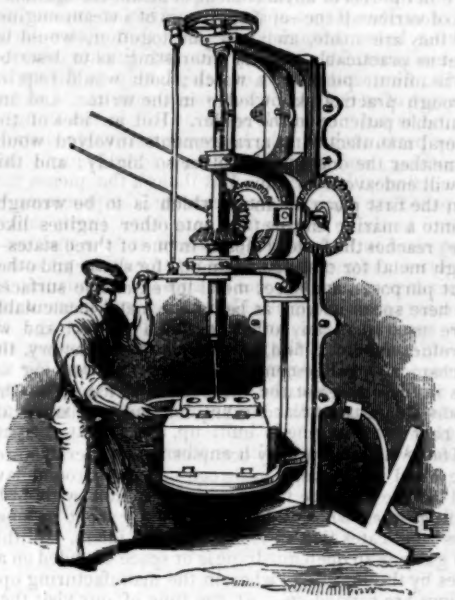
Let us next notice a little more closely a few of the operations here indicated. We may begin with the boiler. This very important part of a steam-engine, when it is considered that water and high-pressure steam have to be contained in it, may well be supposed to require careful manufacture. Mr. Scott Russell observes:—"The construction of a boiler must appear so simple an arrangement of materials, as to require very little ingenuity or contrivance; a large enough boiler placed upon a large enough fire being sufficient to generate any requisite supply of steam. Simple, however, as such an arrangement may seem, the best construction of boiler is a subject upon which very widely different and even opposite opinions are entertained by men of the greatest science and experience." So far as the practical construction goes, however, and without reference to the choice of form, the operations are somewhat as follow:—Whether the boiler be of copper or of iron (copper being the most durable, but iron the most frequently used, probably on account of its greater cheapness), the sheets are chosen of such thickness as is deemed necessary to give the strength required, and is cut to such sizes as will, when bent into the curved shape, form the boiler. Sometimes cast-iron-plate boilers are used; but sheet-metal is much more prevalent. Every sheet or piece being attached to the adjoining one by rivets, the piercing of the holes for these rivets is one of the preliminary operations in boiler-making. The punching-machines employed in engineering differ a little in their construction, but they are always so strongly made, and urged by so great a power, as to pierce through metal with the greatest ease. The punch employed of course varies in size according to the hole to be pierced; but whatever be its size, the sheet of metal is placed beneath it, adjusted accurately, and then pierced through, the small piece of metal falling into a receptacle beneath. The plate or sheet is shifted on a few inches at a time, and pierced in the same way, until the whole outer edge of the metal is pierced. In most instances the cutting-engine and the punching-engine are distinct and separate; but the wood-cut on p. 381 represents a double machine comprising both of these parts. The ponderous upper bar has a punch at one end and a kind of scissor-blade at the other, [which, through the vibratory movement of the bar, are brought alternately into action.

All the pierced plates for a boiler require a certain modification of surface to adapt them to the curvature of the boiler. This is effected by hammering on an anvil, a gauge or pattern being applied from time to

time to determine the character and amount of curvature. This being effected, the sheets are then fastened together by riveting; and this is in every respect a remarkable process. By the side of the boiler-maker is a small portable forge, expressly intended for heating the rivets. These rivets are short thick pieces of rod-iron with clumsy heads; and before being used they are heated to a red or almost a white heat. The two edges which are to be riveted being lapped one over another, and holes penetrating both of them, a red-hot rivet is put into each hole, and beaten with a powerful hammer until quite hard, by which time the head has become beaten down to a conical form. A man holds a hammer against the other side or end of the rivet, to afford a sufficient resistance to the blows; and he in his turn hammers down the inner end of the rivet. The overlapping edges of the sheet-copper are thus pressed together, not only by the beating which the rivet has received, but also by the contraction which it undergoes by cooling. Every rivet in every joint at every part of the boiler is treated successively in the same way; and thus arises the din and clatter always incident to boiler-making. Funnels for steam-boats, and all large vessels made of sheet-iron or copper, are put together much in the same manner as boilers.

The steam-engine operations connected with casting are very similar in their routine to other kinds of casting. The bed-plates, which go entirely under the engine of a steam-boat, the cylinders, the pistons, the beams, and various other parts are cast in sand in the first instance, and then worked up to a smooth and polished surface. In the case of a cylinder, where both the outer and inner surface are to be regular and uniform, a brick core or mould is built up, in the manner of those used in founding church bells (as described in the Supplement for March, 1842); and an outer casing being also formed, the vacancy between the two forms a receptacle for the melted metal which is to constitute the cylinder. All the cylinders for steam-engines, some of which are of such vast dimensions, are made in this manner. The bed-plates for marine engines are among the most ponderous specimens of casting. We saw one lying at the Vulcan foundry, twenty-four feet long by ten wide, and weighing twenty-four tons. Some are thirty or forty tons in weight, and cast at one time in one mould. These bed-plates consist not merely of a stout plate to go entirely beneath the engine, but also of the large vessel in which the steam is condensed, both being cast in one piece. The formation of the mould for these large pieces, the melting of thirty tons of iron in one furnace, and the casting of this metal without the intervention of air-bubbles or impurities, are among the most important operations of these establishments.

The forges and cast masses of iron, whether for shafts, wheels, cranks, cylinders, or any other portions of an engine, all require more or less finishing and adjustment when they leave the forge and the casting-pit; and these finishing operations constitute the most extensive part of the arrangements in an engine factory. At the Vulcan works, as we before observed, these processes are carried on in several floors of a large building, and involve the use of several distinct classes of working apparatus. One of these, for example, is that for boring cylinders. In the lowest floor of the engineering shop there was a steam-engine cylinder fixed upon the boring-machine, and undergoing the process of boring. This does not consist, as the name seems to imply, in boring a cavity through a solid piece of metal, but in giving a perfectly circular form and smooth surface to that which has already been formed by casting. The motion of a piston in a cylinder, to be smooth and air-tight, requires that the internal surface of the cylinder should be rigorously true; and as this exactitude cannot be produced by casting, it is attained by subsequent boring. The cylinder is placed horizontally, and the boring-instrument consists of a cutting edge or tool which revolves in contact with the inner surface of the cylinder. Some boring-machines, such as that represented in the annexed cut, are employed for furnishing smaller circular apertures, and do not differ much in appearance from drilling-machines.



[Boring-Machine.]

The planing-machines employed in such factories are intended to produce the same effect upon a flat surface as the boring-machines upon a cylindrical surface. Supposing a piece of metal to be cast as flat as possible, but not so level and smooth as the object requires, it is placed horizontally, and the planing-machine passed to and fro over it. There is not to this machine a plane-iron fixed into a box, as for wood-work, but a stout, strong, hard piece of steel, having one edge sufficiently keen to cut away the surface over which it passes, and on which it strongly presses. The beauty of these machines consists in the nice adjustment by which the motion of the cutting edge is kept as one uniform horizontal plane, so as to impart perfect flatness and smoothness to the plate beneath. Our concluding cut represents one of these machines.

Lathes are a kind of working apparatus very extensively used in such establishments. All shafts which have been forged, and all smaller pieces of metal which have been forged or cast, and whose contour is circular, are submitted to the action of the lathe as a means of obtaining perfect circularity of form. The cutting tools are formed of very hard steel, and are applied to the surface of the metal very much in the same way as a wood-turner uses his chisels and gouges. Large wheels, in order to undergo the process of turning after casting, frequently require that a hole should be left in the floor of the shop to admit part of the diameter, as they would else be almost unmanageable.

Screw-cutting machines form another important class of working apparatus, since the screws for a

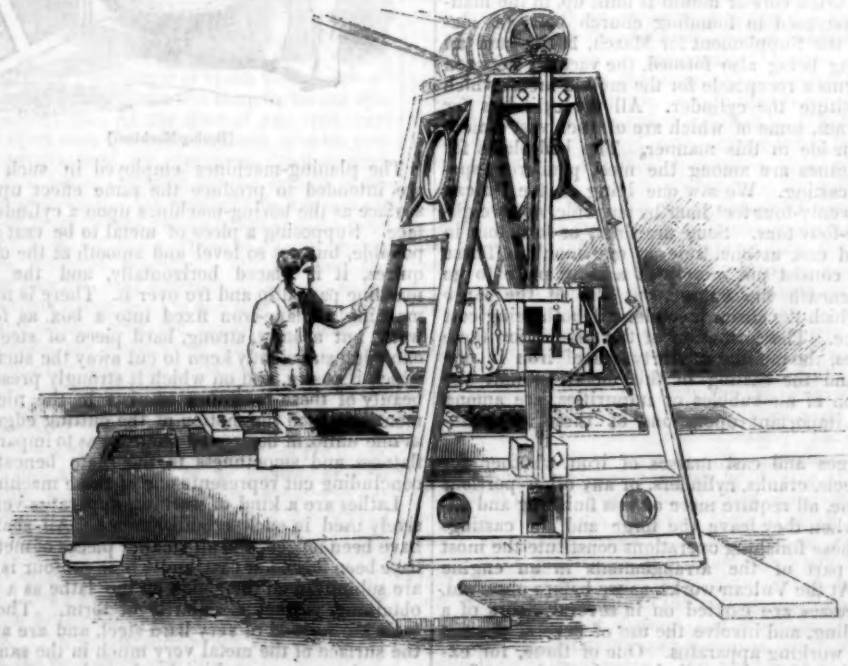
steam-engine, as for any other delicate piece of mechanism, require much accuracy of adjustment. These machines somewhat resemble lathes, in so far as there is a cutting edge applied to a revolving bar of metal; but the distinguishing feature is this, that while the bar which forms the shaft of the screw rotates, the tool which cuts the thread of the screw travels onward from end to end, and the relative velocities of these two movements determine the obliquity of the thread or worm.

In various shops, and in various parts of each shop, are other pieces of apparatus appropriated to the finishing of various pieces of metal. Piercing-engines, for making holes through sheets and thin plates—drilling-machines, for similarly piercing thicker plates—anvils, files, and a host of others, help to fill up the measure of an engineer's working apparatus. A steam-engine is not "one and undivided;" it is a thing of many parts, each of which requires accurate shaping, smoothing, and adjusting, before it is brought into connection with the rest. But though the pieces thus prepared are exceedingly numerous, the processes incident to their preparation have been pretty nearly comprised in those already glanced at: the making of patterns, gauges, and moulds; the casting-pit and its appendages; the forge and its swarthy attendants; the piercing and drilling machines; the cutting-machines; the apparatus and arrangements for riveting; the boring-machines; the lathes and screw-cutting machines; the planing-machines; the hammer, the file, the anvil—these are the agencies, directed by manual dexterity or muscular strength, or both, by which the mighty steam-engine is built up, and its various parts made to combine one with another.

We have spoken of all these arrangements as if in connection with the Vulcan foundry only; but the same will apply in a nearly similar degree to the Lancefield works, belonging to the same firm. These are situated somewhat farther west, but yet in immediate proximity to the Clyde. Here, as at the Vulcan, there is an open yard surrounded by buildings; and in these buildings the processes of forging, casting, planing, turning, &c. are carried on nearly the same as at the other works. We observed many of the rough elements for an iron steam-boat lying about the works: iron bars for the ribs, in one place; huge castings and bent pieces for the stem and stern, in another; quadrangular pieces from which the keel was to be built up, in a third; and so on. In other respects the two establishments are pretty much alike: the one was, we believe, an offshoot from the other, and, like it, gives employment to several hundred men. At the north bank of the Clyde, immediately opposite the end of the street where these works are situated, is a wooden shed or erection, for facilitating the transport of engines and boilers from the works to steam-boats lying alongside: and here we may often see huge boilers, many tons in weight, suspended in mid-air, and gradually descending to their place of reception in the vessel beneath.

Such busy scenes as these which the engineering establishments exhibit, taken in conjunction with the other manufacturing and commercial enterprises of the city, give to the whole an appearance of energy and prosperity well fitted to the motto which the citizens have chosen to adopt:—

"LET GLASGOW FLOURISH!"



[Planing-Machine.]